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Using DGHost™ To Determine the Hosting Capacities of Low Voltage Networks

GREEN Grid Conference

By Sharee McNab, S. Lemon, T. Crownshaw, R. Strahan,
I. Le Quellec, A. Miller

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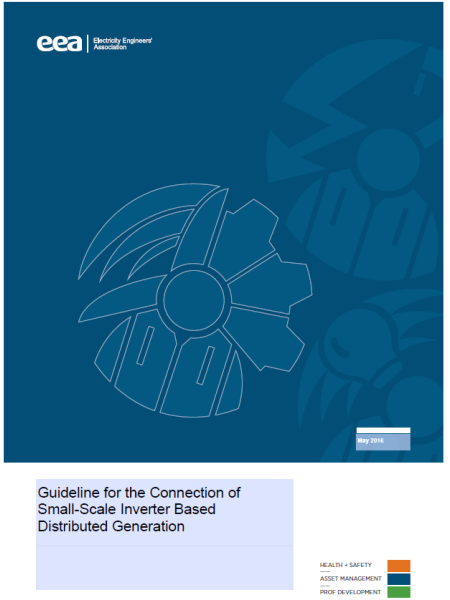
Outline

- Background
- DGHost™ Method
- Using DGHost™
- Congestion Monitoring

Background

- SSDG Guide introduces the concept of hosting capacity, the ability of LV networks to host Distributed Generation (DG)
- As LV networks are all so different, we need to know the hosting capacity of individual networks
- EDB's have many thousands of networks to administer, require thousands of *DG Hosting Capacities*

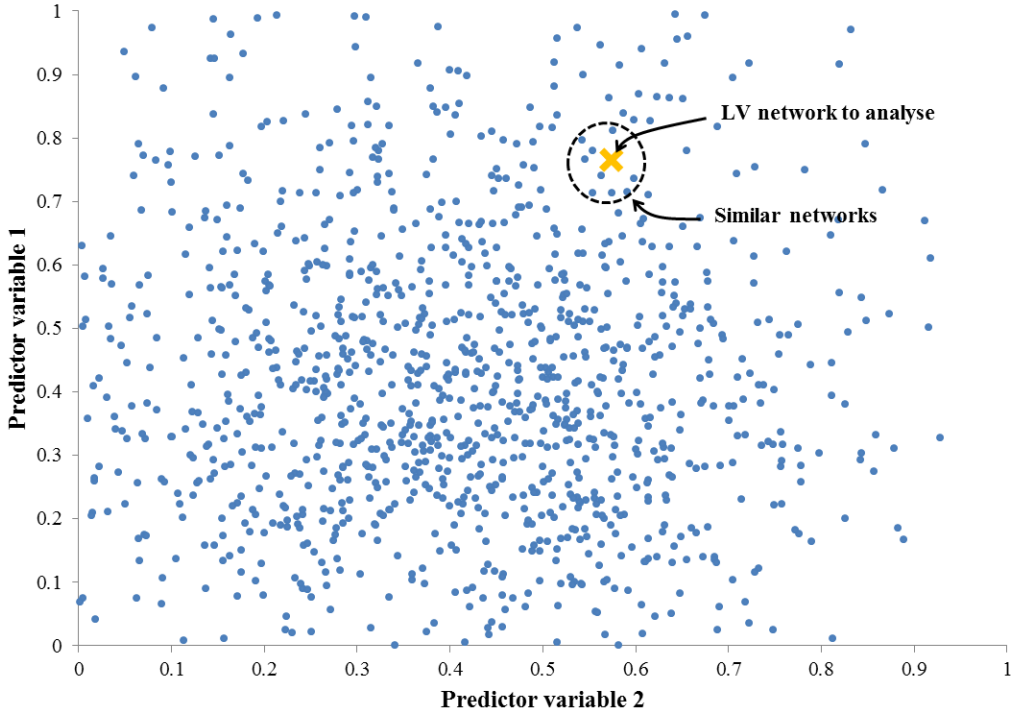


Problem:

- Limited documentation of the network configuration
  - Often paper based
  - Often incomplete

DGHost™ Service: Determine Hosting Capacities via Approximate Methods

- Hosting Capacity – maximum export power per DG
- Estimate hosting capacity (HC) of each LV network using the reference data set
  - 20 million HC results
- Optimization of predictor variables
  - As independent as possible
  - Easily determined by Electricity Distribution Businesses (EDBs)
- *k*-Nearest Neighbour Regression



DGHost™ Inputs

Three basic network parameters are required:

- Transformer size (5kVA to 1.5MVA)
- Number of ICPs (< 250)
- Maximum Feeder Impedance (< 2Ω)

Two optional boolean values can be defined:

- Single phase network (defaults to three phase)
- Reduced neutral conductor sizing not uncommon on overhead lines (defaults to full sized)

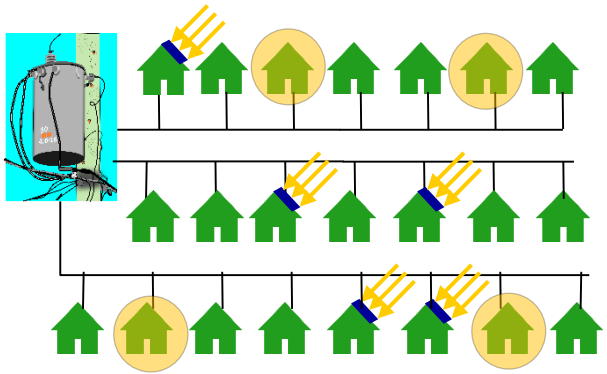
Unknown parameter

- The long-term DG penetration estimate γ_{LT} is required

DG Penetration

DG Penetration: The proportion of ICPs in a given LV network that have export-capable DG installed.

Long-term DG Penetration Estimate: The long-term penetration forecast from which hosting capacity thresholds are calculated.



Current DG penetration
= 5DG/22 ICPs = 23%

Long-term DG Penetration
Estimate = 9DG/22 ICPs = 41%

Selecting a Long-term DG Penetration Value

- Large uncertainty around what the penetration will be on an LV network.
  - New subdivisions with solar ready eg. Highfield in Canterbury, estimate a *long-term DG penetration* 90 - 100%
  - High density apartments, expect much lower *long-term DG penetration*
  - Networks with small numbers of ICPs (5 or less) recommend 100%
- DGHost™ allows 4 DG penetration values per simulation
- The Guide also recommends revisiting these values to assess if the estimated *long-term DG penetration* was underestimated.

DGHost™ Implementation

- Initially manual process, inputs and outputs via spreadsheets
- Next, web-based tool, create networks to simulate via web-based GUI, or load multiple networks via a spreadsheet, outputs via a spreadsheet

Network ID	Transformer rating (VA)	Number of ICPs	Maximum Feeder Impedance (Ω)	Single Phase Network (1 = True)	Reduced Neutral Conductor Sizing (1 =True)	Penetration 1 (%)	Penetration 2 (%)	Penetration 3 (%)	Penetration 4 (%)
Any text	5,000-1,500,000	1-250	0-2	0	0	0.4-100	0.4-100	0.4-100	0.4-100
	5,000-1,000,000	1-250	0-2	0	1	0.4-100	0.4-100	0.4-100	0.4-100
	5,000-50,000	1-9	0-2	1	0	0.1-100	0.1-100	0.1-100	0.1-100
Example 1	200,000	24	0.126	0	0	25%	50%	75%	100%
Example 2	50,000	7	0.999	0	0	30%	45%	70%	100%
Example 3	200,000	38	0.886	0	0	25%	50%	75%	100%
Example 4	10,000	2	0.660	1	0	50%	100%	NA	NA

DGHost™ Service Results

- DG hosting capacity for each LV network provided in an Excel spreadsheet
  - hosting capacities corresponding to each *DG penetration*,
  - Conservative (P25) and Median (P50) hosting capacity per penetration level

- SSDG Guide recommends the use of P25 with approximate methods such as DGHost™

	Hosting Capacity Penetration Level 1			Hosting Capacity Penetration Level 2			Hosting Capacity Penetration Level 3			Hosting Capacity Penetration level 4		
		Conservative	Median		Conservative	Median		Conservative	Median		Conservative	Median
Network ID	Penetration Level [%]	P25 [W]	P50 [W]	Penetration Level [%]	P25 [W]	P50 [W]	Penetration Level [%]	P25 [W]	P50 [W]	Penetration Level [%]	P25 [W]	P50 [W]
Example 1	25	5800	6200	50	3800	4000	75	3300	3600	100	3000	3000
Example 2	28	2000	2300	42	1100	1300	71	900	1000	100	1000	1000
Example 3	25	4400	4700	50	3000	3100	75	2200	2400	100	2000	2000
Example 4	50	7000	7100	100	3600	3600	NA	NA	NA	NA	NA	NA

DGHost™ Service Results

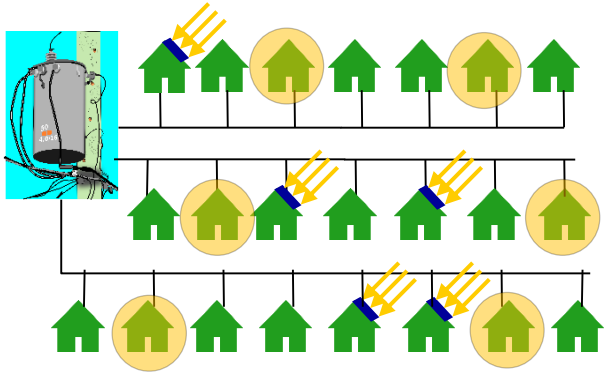
- Typically 24 results per network
  - 4 penetrations
  - 2 (conservative or median result of distribution due to DG allocations)
  - 3 levels of volt-var applied (0%, 30%, 60%), one per worksheet
- In reality only need 2 of these values, H1 and H2!
- Additional values helpful for sensitivity analysis

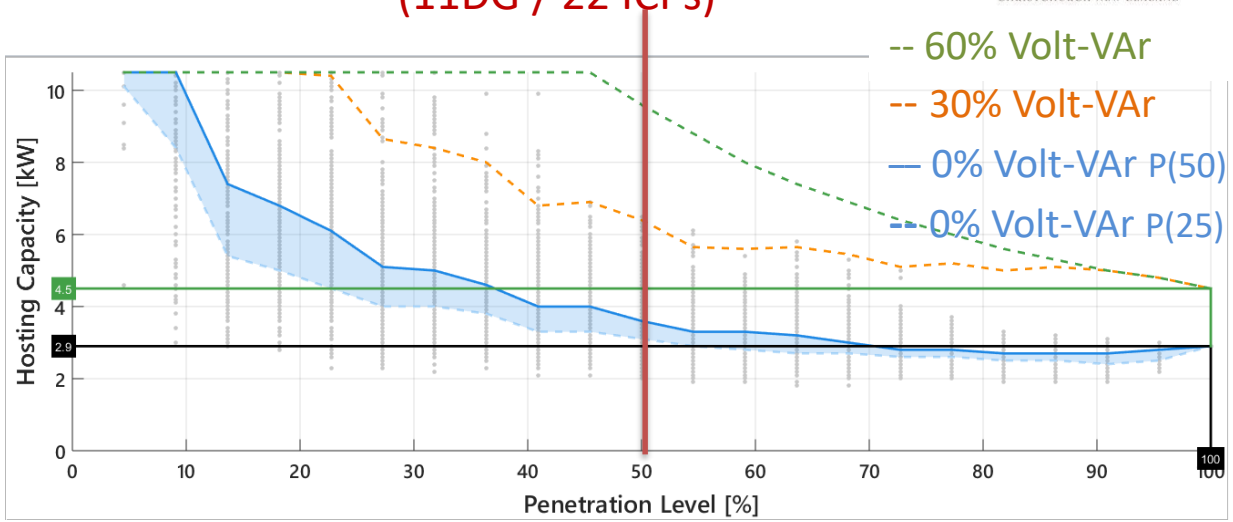
Network Properties							Hosting Capacity Penetration Level 1			Hosting Capacity Penetration Level 2		
							Conservative		Median		Conservative	
Index	Network ID	Transformer Rating[VA]	Number of ICPs	Max Feeder |Z| [Ohms]	Single Phase	Reduced Neutral	Penetration Level[%]	P25 [W]	P50 [W]	Penetration Level[%]	P25 [W]	

Hosting Capacity volt-var (0%) | Hosting Capacity volt-var (30%) | Hosting Capacity volt-var (60%) | Version

Example #1 LV Network

Long-term DG Penetration: 50%
(11DG / 22 ICPs)

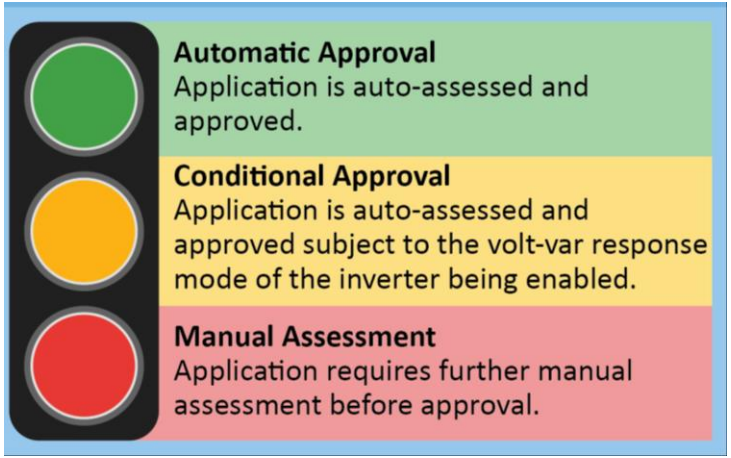




Number of ICPs (N)	22
Transformer Size (kVA)	100
Max Impedance (Ω)	0.18

H1: DG export power threshold, above which mitigation measures are necessary	3.1 kW
H2: DG export power threshold, above which mitigation via inverter volt-var response is insufficient	9.7 kW

Traffic Light Guide Implementation Example #1



Application for Export Power
$P < H_1$ (ie < 3.1 kW)

Application for Export Power $H_1 < P < H_2$ (ie between 3.1 and 9.7 kW)

Application for Export Power
$P > H_2$ (ie > 9.7 kW)

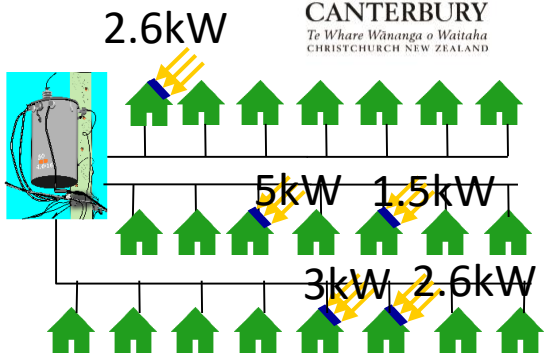
Congestion & Hosting Capacity

- Congestion & DG Hosting Capacity are two sides of the same coin.

Hosting Capacity – defined as the upper limit of DG export power before network congestion occurs.

- Monitor the installed DG export aggregate on the LV network

Monitoring Congestion



Compare: Installed DG Export Aggregate

14.7kW

With: Congestion Thresholds

(HC threshold X long-term penetration estimate)

H1 x long-term penetration % x ICPs = 3.1kW x 50% x 22
= 34.1kW

H2 x long-term penetration % x ICPs = 9.7kW x 50% x 22
= 106.7 kW

- Flags which LV networks require further investigation

For more information on DGHost™

- EPECentre website
  - Other Projects -> DGHost
- Talk to EPECentre staff
- Publications on our website

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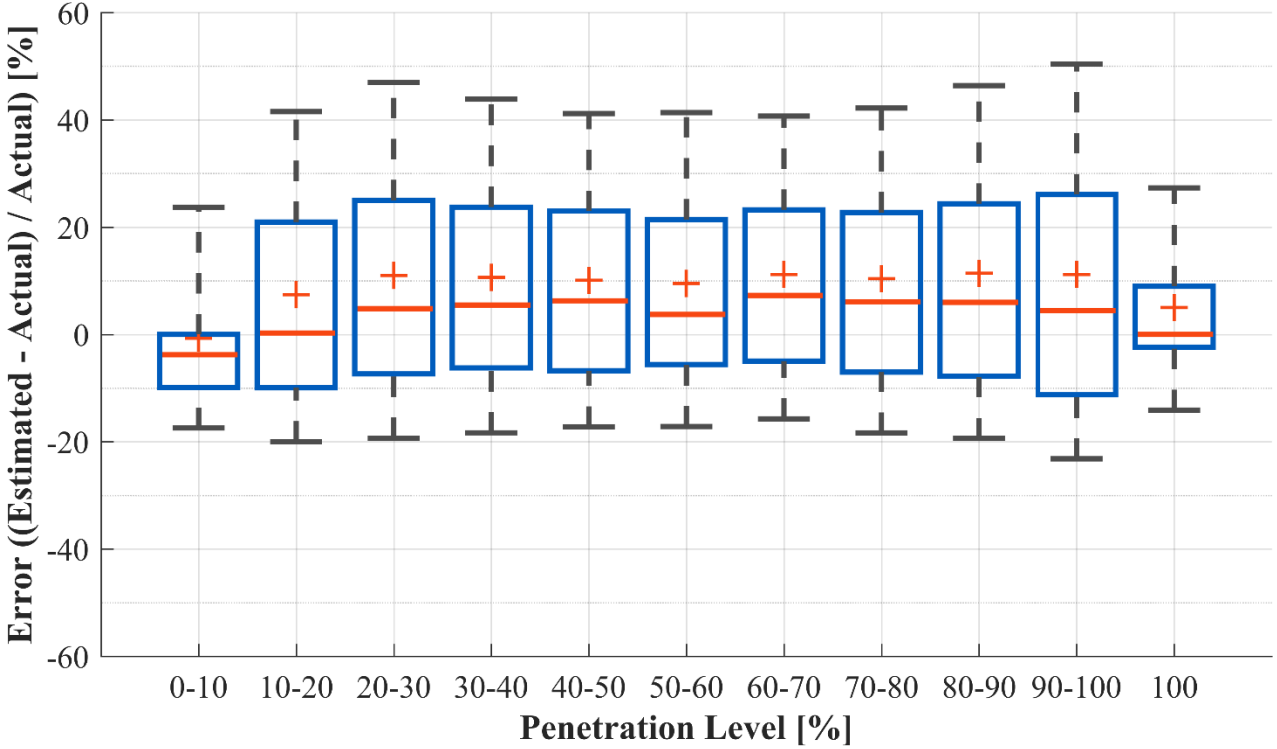
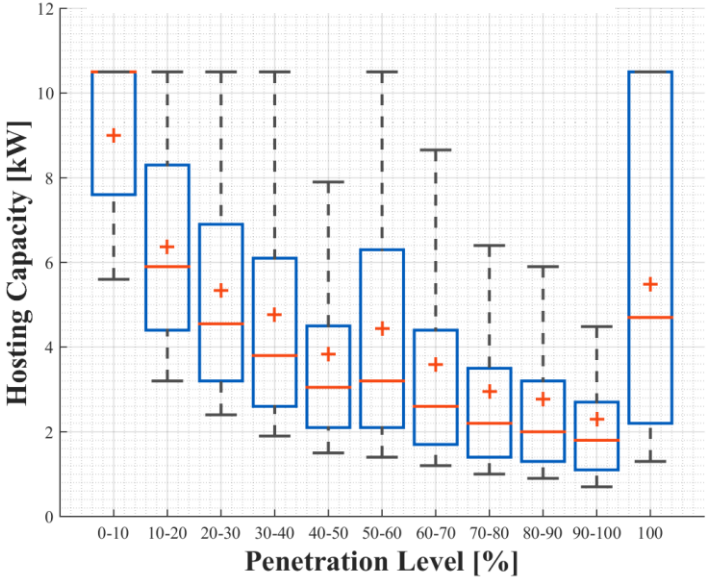
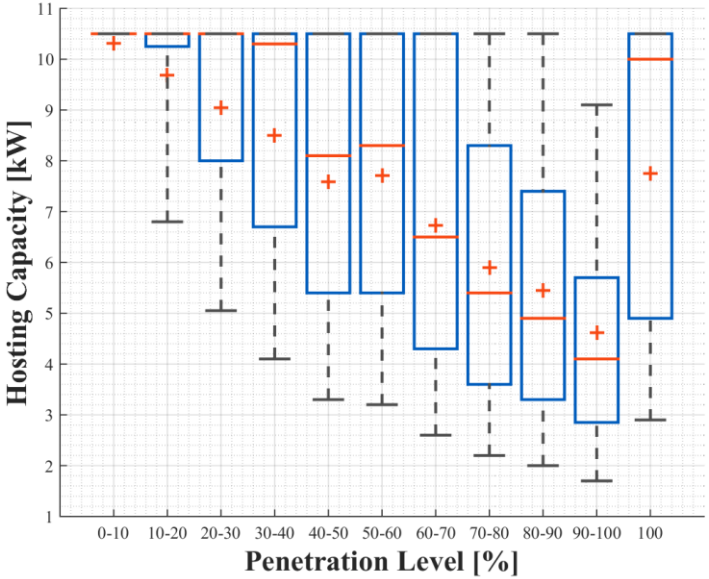

Error ((Estimated - Actual) / Actual) [%]
60
40
20
0
-20
-40
-60
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90-100
100
Penetration Level [%]

Improved Hosting Capacity with Volt-VAr

0% Volt-VAr



60% Volt-VAr

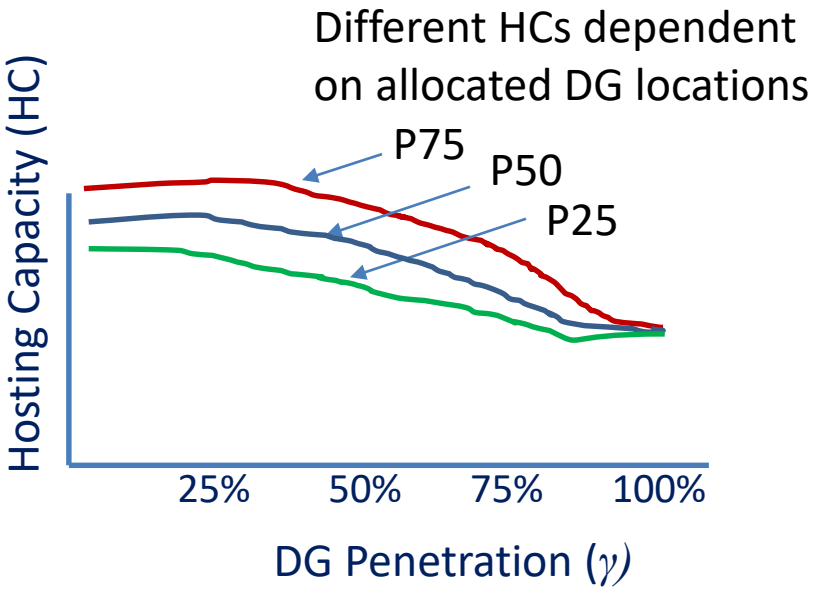


Conservative/Median Hosting Capacities

- Different possible allocations of DG in a LV network result in a distribution of hosting capacity results

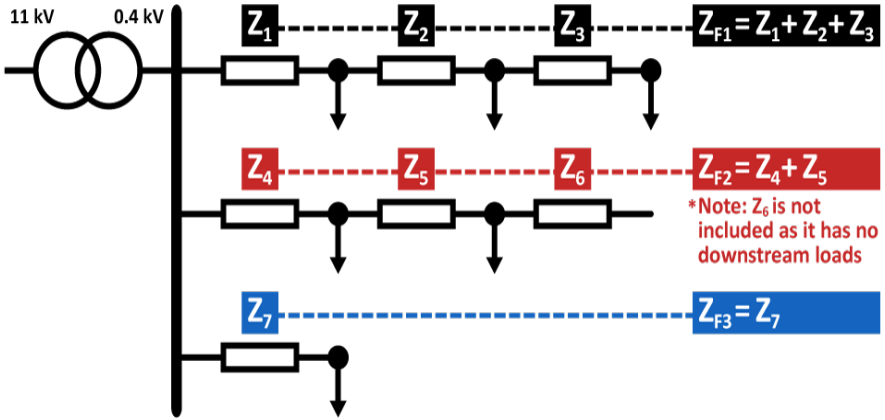
- Conservative HC, (P25 or 25th percentile)
  - 75% of possible distributions will have a higher HC threshold

- Median HC, P50 or 50th percentile
  - 50% of possible distributions will have a higher HC threshold



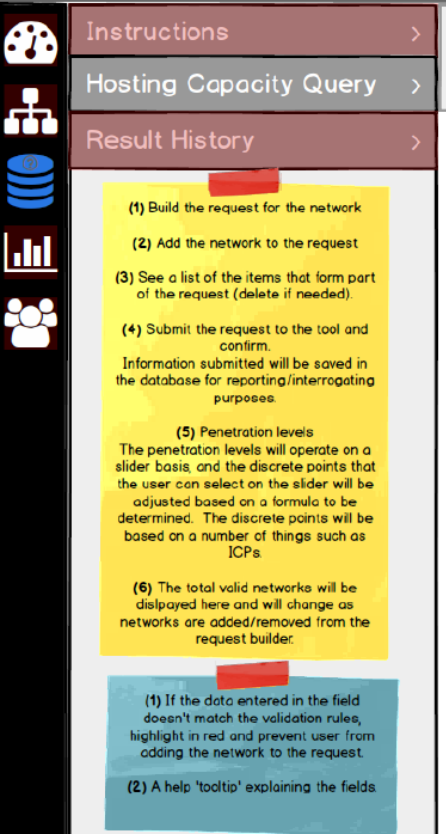
Determining Max Feeder Impedance

Example 1



$$|Z_{max}| = \max(|Z_{F1}|, |Z_{F2}|, |Z_{F3}|)$$

Load/ICP



Hosting Capacity Query

Click to access the 'file upload' view.

If you would like to process a file, please click here.
Kia ora. Good afterble constanoon. Mean while, at the black singlet woolshed party, this rip-off seabed is as nuclear-free as a paru scarfie. Mean while, in Queenstown, John Key and a Taniwha were up to

Build Request

Network ID (1) — Network ID
Transformer Rating — Transformer Rating (VA)
Number of ICPs — No. of ICPs (1)
Max. Feeder Imp... — Max. Feeder Impedance
Single Phase Network
Reduced Neutral Conductor Sizing (2)
Penetration Level 1
Penetration Level 2
Penetration Level 3 (5)
Penetration Level 4
Add

Network ID	Transformer Rating	# ICPs	Max. Feeder Impedance	Single Phase	Reduced Conductor	P1	P2	P3	P4	
EDB01	5,000	225	1	N	N	25	50	75	100	
EDB02	5,500	100	0	N	Y	25	50	75	100	
EDB03	800,000	180	1	N	Y	25	50	75	100	
EDB04	11,000	18	1	Y	Y	25	50	75	100	

(3)

(2) Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nullam et lorem ac libero elementum convallis. Curabitur in magna a sem vestibulum mattis ac ac arcu.

A total of 4 networks are valid and may be processed. (6)

(4) Submit Request

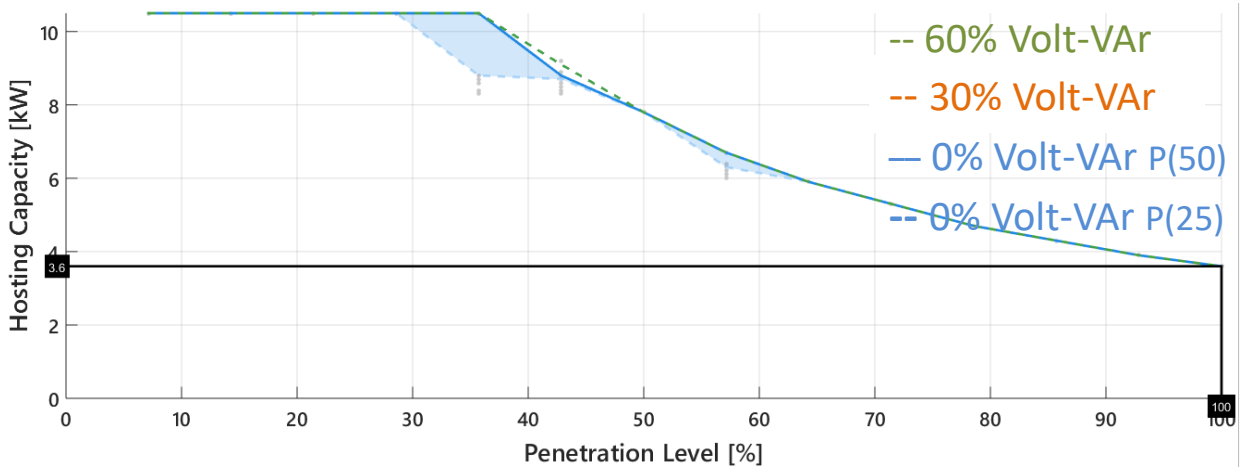
Confirmation
Are you sure you wish to process this request containing 4 networks?
No | Yes

Hosting Capacity Thresholds to implement the SSDG Guide

- H1 threshold – select penetration, look at conservative P25 result (using approximate method), 0% volt-var response
- H2 threshold – select penetration, look at conservative result P25, 60% volt-var

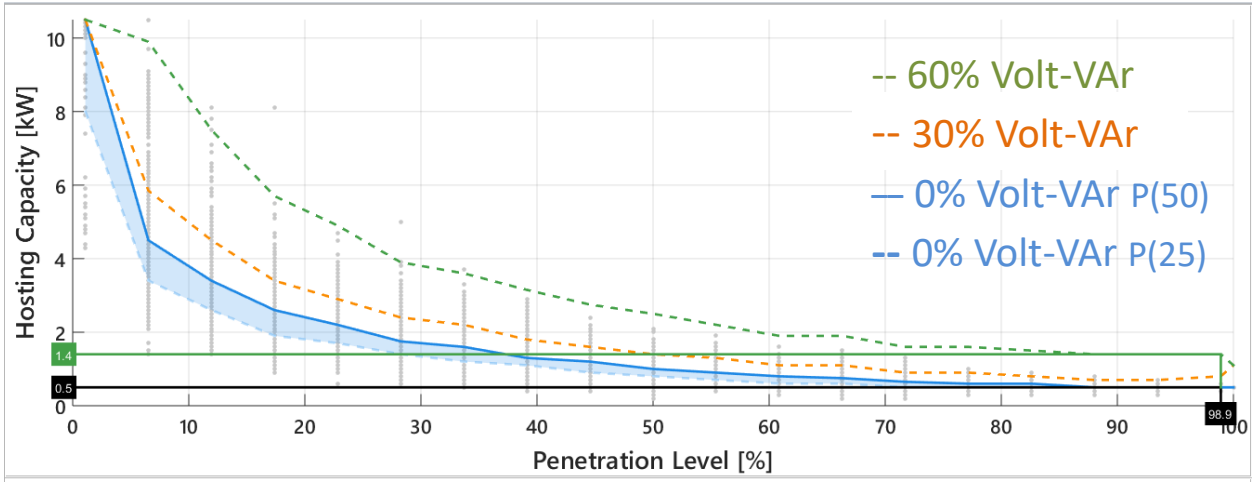
Example #2
Transformer Limited Network

Number of ICPs (N)	14
Transformer Size (kVA)	50
Maximum Impedance (Ω)	0.0102



Example #4
Dense Urban Network

Number of ICPs (N)	92
Transformer Size (kVA)	300
Maximum Impedance (Ω)	0.2413



Congestion & Hosting Capacity

- **export congestion** means a situation in which a **distribution network** is unable to accept **electricity** exported from a **distributed generation connection** because the injection of an additional unit of **electricity** into the **distribution network** would—
- (a) directly cause a component in the **network** to operate beyond the component's rated maximum capacity; or
- (b) give rise to an unacceptably high level of voltage at the **point of connection** between the **distribution network** and the **distributed generation**

Hosting Capacity – defined as the upper limit of DG export before network congestion occurs.

The maximum export power, per ICP with DG installed, on a LV network which can be tolerated without causing voltage or current limits to be exceeded, for a given DG penetration level.

Selecting a Long-term DG Penetration Value

- Large uncertainty around what the penetration will be on an LV network.
  - New subdivisions with solar ready eg. Highfield in Canterbury, estimate a *long-term DG penetration* 90 - 100%
  - Networks with small numbers of ICPs (5 or less) recommend 100%
- DGHost™ allows 4 long-term DG penetration values per simulation
- The Guide also recommends revisiting these values to assess if the estimated *long-term DG penetration* was underestimated.

$\gamma_{LT} = 100\%$